

# A Maintenance and Operations Cost Model for the DSN

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*A cost model for the DSN is developed which is useful in analyzing the 10-year Life Cycle Cost of the Bent Pipe Project. The philosophy behind the development and the use made of a computer data base are detailed; the applicability of this model to other projects is discussed.*

## I. Introduction

The term "Bent Pipe" is used to describe the concept of employing high-capacity satellite and terrestrial microwave communications links to relay data streams, which now are visible only to pieces of equipment fixed at the DSN stations, between simplified antenna station installations remaining at the existing sites, and a data processing and control center where equipment from the remote stations has been relocated. It is anticipated that the increased use of satellite relay links will permit the removal and relocation of a sufficient amount of equipment from the stations to allow a reduction in maintenance, operations, support, and sustaining engineering costs to the DSN. A study is underway to assess not only the feasibility of this concept, but also the life-cycle cost to the DSN of the adoption and implementation of the Bent Pipe plan. This article discusses a technique developed for esti-

imating the resulting long-term effects on the aforementioned costs and incorporating these estimates into a calculation of the overall life-cycle cost of the project.

This study began with an investigation of the way money is currently spent in the DSN. A rough model constructed as a result of this investigation was extended to future years to see how the DSN budget might be expected to behave without the implementation of the Bent Pipe project. The model was constructed in such a way as to pick out those parts of the total budget which are likely to be affected by the implementation of this plan, and so it becomes a relatively painless task, once the form of the model is fixed, to predict the savings which can accrue over a ten-year period during which the plan is in operation. The aim in developing this technique was to produce numbers which are accurate within 20 percent.

## II. Constructing the Model

The process of constructing the model can be broken into distinct steps, which are individually detailed in the following paragraphs. These steps are almost entirely project-independent, in that the resulting model structure would be the same if any major reconfiguration of DSN equipment were used as the basis.

### A. Identification of Accounts Related to Maintenance and Operations

Approximately 650 accounts registered in the WAD, JPL's Work Authorization Document, are currently funded. For each, a description of the work funded by the account is contained in a Format A Document, along with a listing of the appropriate JPL and NASA account codes. The first task in this project was to study these Format A's in sufficient detail to be able to discern which of the accounts were related to maintenance and operations and, in turn, which of these were likely to be affected by a major reconfiguration.

### B. Creation of the Computer Data Base

The very large number of accounts or entries in the cost model made the process of manipulating them unwieldy and so the development of the model was aided immeasurably by the availability of an easily manipulated data base existing on the Univac 1108. Records containing extensive information from WAD 76-2, the January 4, 1977 version, about each account are contained in the WAD file on that machine. A file structure compatible with the WAD file was created by the JPL Data/Management Information/Retrieval System (JPLDIS) processor, and the WAD file, as illustrated in Fig. 1, Step 2, was appended. Abbreviations of the data fields shown in that figure have the following meanings:

ACCT:TITLE = Account Title  
NASA:CODE = NASA Account Code  
JPL:CODE = JPL Account Code  
CTR XX = Contractor Work Years  
JPL XX = JPL Work Years  
OBLN XX = Obligation in thousands of dollars  
COST XX = Cost in thousands of dollars

where

XX = Fiscal Year, e.g., FY77 = XX

### C. Categorization of Affected Accounts

The descriptions of all accounts pertaining to maintenance or operations were studied again in order to assign each to one of five major functional categories. The decision as to how many functional categories to distribute the affected accounts

among, and which set of functional categories to choose was influenced by a desire to keep the number of categories small, but at the same time find a set which would be complete in that the combination would reasonably describe all phases of operation of the network. The four functional categories chosen are: maintenance, operations, M&O support, and sustaining engineering. In addition, it can be assumed that all accounts determined to be unrelated to maintenance and operations fall under a fifth functional category called "fixed." Examples of accounts falling into each functional category are found in Table 1. Accounts that support M&O activity but are not directly related to hardware maintenance or facility operations were placed in the M&O support category.

The full complement of fields attached to each account record includes two more: location and subsystem. The four possible entries in location — JPL, GDSCC, Spain, and Australia — indicate where activity performed under the auspices of the account took place. Accounts used in direct operational support of existing equipment were tagged GDSCC, Spain, or Australia, as appropriate; most other accounts were labeled with a JPL location. The addition of this field lent to the model the ability to register a modest increase in the operations funds spent at JPL along with the anticipated decrease in operations funding at the stations. In addition, this field is necessary to give the model sufficient flexibility to handle cases in which the final project plan will affect each geographical location differently.

The subsystem field contains an entry only where appropriate. Accounts in the support functional category are assumed to have an impact on all subsystems. Most sustaining engineering accounts, however, are specific to one or more subsystems. This data field is particularly important in the Bent Pipe Project since each configuration will affect a different set of subsystems, and so some accounts will be touched by some configurations and not by others. For example, the telemetry Bent Pipe configuration would result in the relocation of telemetry equipment while command subsystem equipment would remain unaffected. In this case it is expected that half of the displaced telemetry equipment could be deimplemented, while half is transported to the central processing site. Table 2 presents two accounts with their associated functional category, location, and subsystem fields.

The point at which this data was entered into the data base is illustrated in Fig. 1, Step 3.

### D. Creation of the Cost Model

At this point there was sufficient information in the modified WAD File to create a file suitable for estimating future costs. A new file structure, COST MODEL, was created as shown in Step 4 of Fig. 1. The entries in this file were created

by subtotalling the cost columns in the modified WAD file by location, category and subsystem. This reduced the data base to a very manageable form where the resulting 28 subtotal groups were treated as the smallest individual entities to be entered in the model. Some of these groups contained well over 100 accounts, some contained only one. The result of this JPLDIS sort and subtotal operation is displayed in Table 3, which details the contents of COST MODEL as displayed at the 1108 terminal. The subsystem acronyms used in that table are those prescribed for use by JPL Standard Practice. Since WAD 76-2 did not contain M&O cost entries for FY81 and FY82, these years were dropped from the cost model at this point. These data points are subsequently filled with estimates. At this point, the number of file records had been reduced from 650 to 28, greatly reducing the data handling effort, and setting the stage for a reasonable and hopefully well-reasoned cost modeling effort.

### **E. Extension of Cost Entries to FY86**

The calculation of a ten-year life-cycle cost requires, of course, ten data points not four, and so a program was developed on the Sigma 5 computer to fill in the future cost blanks for the 28 subtotal groups in the model from FY81 through FY86. A least squares fit was performed on the available cost data to the optimum exponential curve passing through the FY80 point. These extended cost estimates were added to the data base as shown in Fig. 1, Step 5. It is important to note that extensions were not made for individual accounts, but rather for subtotals belonging to logical groups of accounts, for it is only when the data is collected and treated in this form that FY77 through FY80 cost figures are sufficiently well behaved to allow this curve fit.

### **F. Bent Pipe Reduction Factors**

Figure 1, Step 5, also shows the addition of a field labeled COEF to each record, now in its final form. Obviously, the model has been constructed in such a way that adding the

FY77 cost figures from all 28 subtotal groups will yield the total current M&O and sustaining engineering budget for the DSN; the estimated FY86 budget can be obtained similarly. However, if each of the 28 sets of 10 cost figures is multiplied by a factor which reflects how much that entry can be expected to change due to the Bent Pipe project, the sum then yields the estimate of a particular year's budget after implementation. The ten-year life-cycle cost of the project is then easily derived.

It is central to the usefulness of this model to make valid and well reasoned estimates of these reduction factors; it is also very difficult. In preliminary findings for a telemetry Bent Pipe configuration the following are exemplary of the techniques used to determine these factors:

- (1) Sustaining Engineering — utilized percentage breakdown of the total number of Engineering Change Orders (ECRs) written in 1976 by subsystem.
- (2) Maintenance — utilized percentage breakdown of work orders at stations or Equipment Event Reports (EERs) at CMF and DMC by subsystem.

## **III. Conclusion**

In the course of the Bent Pipe feasibility study, a valuable tool has been developed for estimating maintenance, operations, support, and sustaining engineering cost savings resulting from this proposed major reconfiguration of DSN equipment. The model was developed in such a way as to facilitate its use in rapidly evaluating savings from several different versions of an implementation plan, especially since much thought was given to creating a computer data base in an easily manipulated form. With some modification this tool can prove useful to the life-cycle costing effort in the planning stages of other projects.

## **Acknowledgements**

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**Table 1. Functional categories and FY77 totals**

Category	Account title	JPL: code	FY77 cost
Maintenance (MNT)	M&O CONTR GDSCC MAINT FAC	451-38120-377	393k
Operations (OPS)	M&O CONTR DSS-11 OPS	411-38102-377	517k
M&O support (SUP)	GDSCC ENERGY	411-38112-377	578k
Sustaining engineering (SUS)	RCV-EXC ECC ENG	411-70153-333	39k
Fixed (FXD)	DSN RFI ANALYSIS	411-72922-339	125k

**Table 2. Functional category, location and subsystem examples**

ACCT: TITLE	Cost 77	Cost 78	Cost 79	Cost 80	CAT	LOC	SUBSYSTEM
RCV-EXC ECO ENG	39k	41k	42k	45k	SUS	JPL	RCV
GDSCC ENERGY	578k	619k	680k	760k	SUP	GDSCC	ALL

**Table 3. Contents of cost model file**

LOC	CAT SUBSYSTEM	Cost 77	Cost 78	Cost 79	Cost 80
AUST	OPS	4933	5316	5728	6172
SPAIN	OPS	5076	5470	5894	6351
GDSCC	FXD	605	654	694	732
GDSCC	MNT ALL	4313	4780	5314	5554
GDSCC	OPS ALL	1887	1987	2058	2181
GDSCC	SUP	3439	3828	4019	4274
JPL	FXD	32182	42591	45956	52528
JPL	MNT ALL	217	85	89	94
JPL	MNT GCF/NOCC/CTA	284	300	317	334
JPL	MNT NOCC	839	887	939	989
JPL	OPS ALL	1341	1438	1529	1633
JPL	OPS NOCC	54	57	59	62
JPL	SUP	1105	1105	1156	1185
JPL	SUP GCF/NOCC/CTA	79	81	85	88
JPL	SUS ALL	5911	6301	6642	7029
JPL	SUS DMC/FTS/PPR/DTT	295	328	363	365
JPL	SUS DTK	80	86	51	54
JPL	SUS DTK/APS	92	103	110	118
JPL	SUS DTK/RCV/FTS	109	104	89	81
JPL	SUS DTM	205	234	296	299
JPL	SUS DTM/DCD	208	165	173	190
JPL	SUS DTM/DCD/DTK/GHS/NCS	29	128	142	152
JPL	SUS DTM/DCD/DTK/NCS/DMC/DTT/GHS	522	555	579	614
JPL	SUS NOCC	211	354	552	576
JPL	SUS PGM LIB	375	345	361	379
JPL	SUS RCV	106	106	92	85
JPL	SUS RCV/UWV/TXR/PPR/FTS	214	225	239	250
JPL	SUS SMC	71	103	106	110
GRAND TOTALS		64782	77716	83632	92479

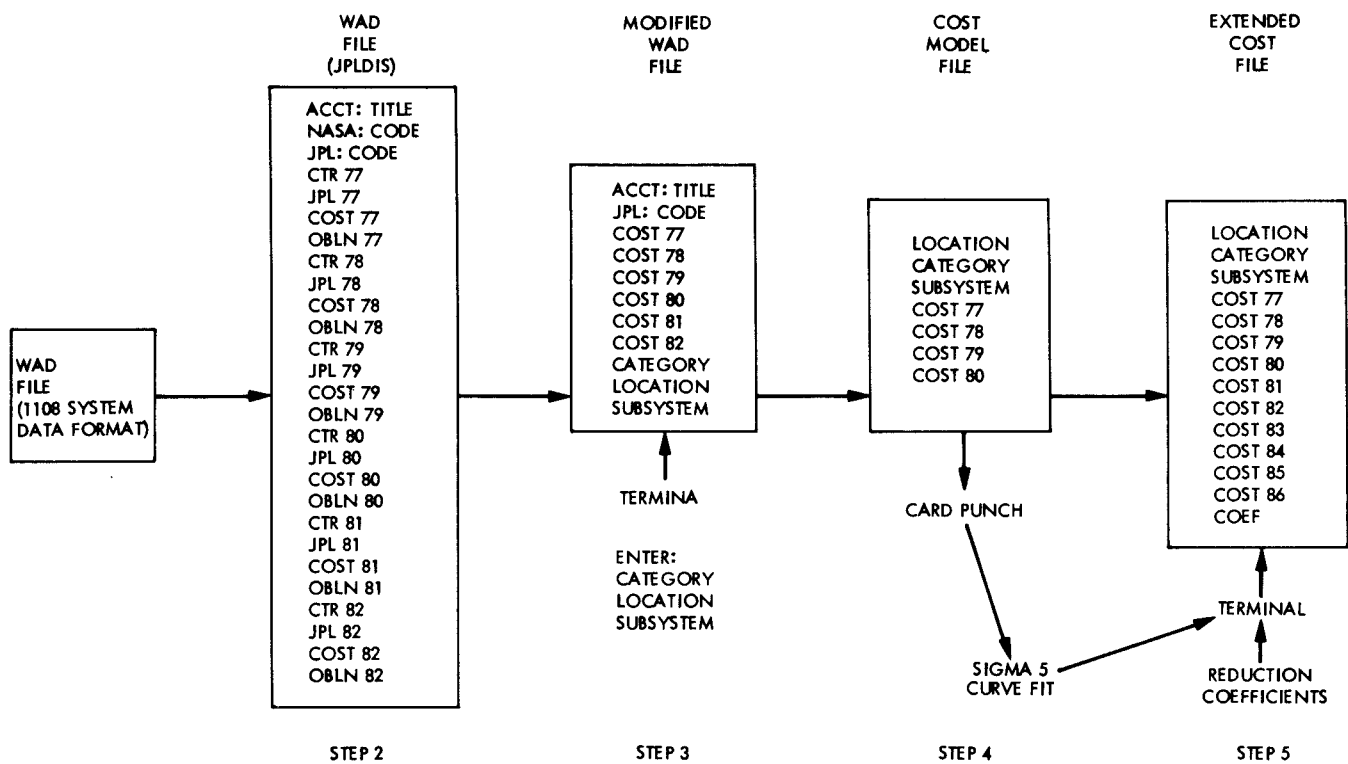


Fig. 1. Bent pipe cost model file evolution